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치의학석사학위논문

Correlation between bone quality evaluated by CT and implant primary stability in the posterior maxilla

상악 구치부에서 골질과 임플란트 초기 안정성 사이의 상관 관계에 관한 연구

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서울대학교 대학원

치의과학과 치과보철학전공

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위 원 장 (인)

부위원장 (인)

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-ABSTRACT-

Correlation between bone quality evaluated by CT and implant primary stability in the posterior maxilla

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Objectives. The aim of the present study was to examine the bone density objectively in implant sites of posterior maxillae using computed tomography and to evaluate possible correlations between age, gender, geometry of implants (design, diameter), maximum insertion torque measurements, and resonance frequency analysis (RFA) values.

Methods. 30 patients who treated with 60 implants in posterior maxilla area were evaluated. Two different types of dental implants were used (30 SLActive® Bone level implant and 30 CMI IS-II active®). The bone densities in each implant site were determined using CT and categorized according to Misch's classification. The maximum insertion torque data and resonance frequency analysis (RFA) measurements were recorded.

Results. 30 patients who treated with 60 implants in posterior maxilla area were evaluated. Two different types of dental implants were used (30 SLActive® Bone level implant and 30 CMI IS-II active®). The bone densities in each implant site were determined using CT and categorized according to Misch's classification. The maximum

insertion torque data and resonance frequency analysis (RFA) measurements were recorded.

Conclusions. The bone density evaluated by CT showed a significant correlation with the primary stability parameters. These values can provide the implant surgeon with an objective assessment of bone quality, which could result in modification of surgical technique, especially in situation where poor bone quality is suspected.

Keywords : bone density, Hounsfield Units, insertion torque, resonance frequency analysis, Posterior Maxilla.

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KOREAN ABSTRACT

Ⅰ. INTRODUCTION

Numerous studies regarding dental implant treatment have showed successful results [1]. The success of implant procedure requires both of patient-related (e.g., bone quality and quantity) and procedure dependent factors (e.g., geometry of implant and surgical procedure). While the bone quality and quantity cannot be modified by the operator, implant design and surgical techniques are factors that can be controlled [2].

The term bone quantity is most often understood as the amount of bone (e.g., height and width of the alveolar crest) available for implant installation, whereas bone quality is a far more comprehensive term with no clear definition, encompassing several aspects of bone physiology, degree of mineralization, and structural properties (architecture, morphology) [3].

Several classification systems were proposed for assessing the bone quality and predicting prognosis. The classification suggested by Lekholm and Zarb has been used widely because it is easy to apply. They listed bone density into 4 types based on the amount of compact versus cancellous bone in a region of the alveolar bone observed on pantograph film. The term quality was introduced to refer to these density types [4].

Quality 1: Almost entire jaw is comprised of homogenous compact bone

Quality 2: A thick layer of compact bone surrounds a core of dense trabecular bone

Quality 3: A thin layer of cortical bone surrounds a core of dense trabecular bone

Quality 4: A thin layer of cortical bone surrounds a core of low density trabecular bone.

Misch further characterized the 4 bone density classes based on the tactile sense of the clinician placing the implant [5].

However, a distinction between the 4 types of bone has not been clearly established. A comparative study between histomorphometry of trabecular bone volume and subjective perception of drilling resistance using the Misch classification by Trisi & Rao reported a strong correlation for densities classified as D1 or D4. However there was a high degree of variation for bone classified as D2 or D3 [6]. Therefore these classifications have provided only subjective methods and recently been questioned due to poor objectivity and reproducibility.

In 1987, computed tomography (CT) was introduced to evaluate bone images before implant placement by Schwarz. CT is an excellent tool for assessing the relative distribution of cortical and cancellous bone. Bone density can be evaluated using Hounsfield units (HU), which are directly represented to tissue attenuation coefficients. The Hounsfield scale is based on density values for air, water, and dense bone, which are assigned arbitrarily values of – 1,000, 0, and +1,000, respectively. Using these parameters to establish a relative scale, a range of values was provided for different types of bone, including very dense cortical bone (> 600 HU), and cortical-spongy bone of low density (< 200 HU) [7]. Misch used computed tomography (CT) to objectively classify bone density into 5 types based on HU: D1, >1,250 HU; D2, 850–1,250 HU; D3, 350–850 HU; D4, 150–350 HU [5]. D4 bone requires careful planning for type and number of implant, surgical procedure and loading protocol. The Hounsfield scale has been used to evaluate bone for implant placement, and the results were considered site specific, objective, and quantitative.

CT constitutes an important supplement to subjective bone density evaluation, since wide ranges of HU values have been observed within each of the four Lekholm and Zarb classes. Norton and Gamble reported a strong correlation between bone density and subjective bone quality scores, as well as between bone density scores and different regions of the mouth, demonstrating that an objective bone density scale based on the Hounsfield scale can be established. They proposed that a new classification be adopted whereby established quantitative ranges are applied to the subjective quality classification as previously described by Lekholm & Zarb. Since it is difficult to distinguish between the two groups, qualities 2 and 3 have been combined into one group. An additional category 4*, can be described as the failure zone [8]. In addition, Bahat et al proposed a subdivision of the classification of type IV bone, referring to bone type V in situations with a complete absence of cortical tissue (upper and lower) [9]. De oliveira et al evaluated the correlation between trabecular bone density measurements of potential implant sites and bone densities in Hounsfield units (HU) with subjective classification. They concluded that bone type 2 was the most prevalent, and bone density was significantly reduced from bone type 1 to 4. They ranged quantitative parameters as follows: bone type 4< 200HU, bone type 2 and 3 > 200 to <400, and bone type 1>400 HU [3]. Herekar et al proposed a scoring index that will establish a correlation among the bone density values from computed tomography, maximum insertion torque values, and resonance frequency analysis in different phases of implant treatment [10].

Notably, the poorest bone quality in the oral cavity typically exists in the posterior maxilla. Shapurian et al reported that the mean bone densities in the anterior mandible, anterior maxilla, posterior maxilla, and posterior mandible were 559, 517, 333, and 321 HU, respectively, at 219 implant sites [7]. And Sogo et al reported that more than 80% of the posterior maxillae was classified as D4 (150-350HU) or D3 (350-850HU) by Misch's classification, comprising averages of 32% and 50% respectively (11). They

concluded that more than 80% of the edentulous posterior maxillae consisted of porous cortical or no cortical bone. Although the majority of bone in the posterior maxillae was classified as D3 or D4, there were remarkable variations among individual subjects. So they proposed to create subcategories within D3 and D4 for more detailed evaluation of bone density.

Many studies suggest that dental implants for the mandible have higher survival rates than those for the maxilla, especially for the posterior maxilla. Clinical studies by De Backer et al and Turkyilmaz et al have shown a higher survival rate for the dental implants in the mandible [12, 13]. More failures for the immediately/early-loaded maxillary implants have also been reported [14]. Goiato et al analyzed a total of 3937 patients, who had received a total of 12,465 dental implants and reported that the survival rates of dental implants according to the bone density were: type I, 97.6%; type II, 96.2%; type III, 96.5%; and type IV, 88.8% [1].

Implant stability is an important parameter for the long-term success of implants. There are two terms associated to the implants; the primary and the secondary implant stability. Primary stability is associated with the mechanical engagement of an implant with the surrounding bone, whereas bone regeneration and remodeling phenomena determine the secondary stability to the implant. A secure primary stability is positively associated with a secondary stability. Primary stability of implants is commonly considered as a key factor for achieving successful osteointegration [15].

Primary stability of the implant can be defined as the absence of implant movement, including micro-motions, immediately after insertion of the implant into the bone bed. Primary stability of the implant mainly depends on bone-to-implant contact. Micro-motions higher than the threshold of 50 to 100μm can lead to formation of fibrous tissue at the bone-to-implant interface. Therefore, osteointegration may be vitiated due to insufficient primary stability [16]. A prospective clinical study by Orenstein et al re-

garding long-term survival rates for both mobile and immobile implants at placement were conducted. They reported that the 3-year survival rate was significantly lower for mobile implants than that for immobile ones [17]. Hence, when immediate loading of the dental implant is preferred as the treatment strategy, primary stability of the implant must be taken into account as a determining criterion.

Several methods have been suggested to determine primary implant stability. One of these methods is the insertion torque measurement described by Johansson and Strid. This method mesures the torque required to place the implant and makes it possible to obtain valuable information about bone quality [18]. High insertion torque value reflects sufficient primary stability of implants and low value reflects low primary stability which has a high risk of early failure [19]. Thus, insertion torque measurement can provide information to predict the proper loading timing and success of implant [20].

Another quantitative method is resonance frequency analysis (RFA), in which implant stability is recorded using a transducer that incorporates piezo-ceramic elements [21]. Resonance frequency analysis (RFA) is a non-invasive technique, which makes it possible to determine primary stability immediately after placement of implant, as well as secondary stability after a period of healing. A metal rod (a peg) is connected to the implant by means of a screw connection. The peg is excited by magnetic pulses and the resonance frequency is expressed electromagnetically as an implant stability quotient (ISQ) with units ranging from 1 to 100 with higher values of the ISQ indicating higher implant stability [22].

The aim of the present study was to examine the bone density objectively in implant sites of posterior maxillae using computed tomography and to evaluate possible correlations between age, gender, geometry of implants (design, diameter), maximum insertion torque measurements, and resonance frequency analysis (RFA) values.

Ⅱ. MATERIALS AND METHODS

The study protocol was reviewed and approved by the Institutional Review Board of Seoul National University Dental Hospital (CMI IRB No. CDE 12001). The participants were informed about the nature of the study and signed the informed consent.

Patients and Implants

A total of 60 implants were included in this study. 30 Patients (male: 20, female: 10) had undergone implant surgery in posterior maxillae. The participants should have a unilateral loss of two consecutive posterior maxillary teeth with the intact occlusal plane opposed with the edentulous surgical site. The inclusion criteria consisted of;

1) Age of 18 years or more
2) Residual bone height of 6 mm or more
3) Sufficient availability of alveolar bone in the surgical site
4) Patient motivation to comply with implant treatment

The exclusion criteria were;

1) Pregnancy
2) A history of recent myocardial infarction
3) Uncontrolled systemic diseases
4) Blood disorders and bleeding problems
5) Other systemic condition that makes surgical intervention hazardous
6) Psychiatric conditions
7) Patients allergic to implant materials

8) Recent tooth extraction or advanced periodontal diseases around surgical sites

9) Sinusitis

10) Bone quality type D4

11) Less than 1 mm buccal or lingual residual width after implant insertion

12) Insertion torque of less than 30 Ncm or greater than 50 Ncm, ISQ < 65

13) Bone graft materials of more than 5 mm

14) Ethical inconsistency to continue participating in the clinical trial

15) A high degree of parafunctional habits and narrow interocclusal space

The preoperative examination included a panoramic radiograph, CT, a clinical examination of the jaws, and diagnostic casts. Two different types of implants were used in this study: SLActive® Bone level implant (InstitutStraumann AG, Basel, Switzerland) and CMI IS-II active® (Neobiotech Co., Seoul, Korea). The SLActive® Bone level implants were 4.1 mm or 4.8 mm in diameter and 10 mm in length, while the CMI IS-II active® implants were 4.0 mm, 4.5 mm or 5.0 mm in diameter and 10 mm in length.

CT Scans

The CT scans were taken by Somatom Sensation 10R multidetector system (Siemens AG, Erlangen, Germany) with following parameters: slice thickness, 1 mm; TI, 0.75 s; 120 kV; and 150 mA/s. OnDemand® software (Cybermed, Seoul, Korea) was used to plot the implants on CT scans. Using this software, three-dimensional information from the post-operative CT image was compared with on the pre-operative CT image. The average density values of the internal and external part of implant were measured using this software.

Surgical procedure

Each participant received 2 implants from the assigned implant system. All implant sockets were prepared according to the manufacturer's instructions using a surgical micromotor by one operator. Implants were placed using single-stage surgery. The surgical procedure was performed under local anesthesia after antimicrobial prophylaxis with amoxicillin 500 mg. The implant sites were exposed through a crestal incision followed by mucoperiosteal flap elevation. In case that maxillary sinus augmentation was needed, a synthetic bone graft material (Calpore, Neobiotech Co., Seoul, Korea) was placed at 5 mm or less in height using a crestal approach. Healing abutments were attached and the soft tissue was sutured in place.

Insertion torque measurements

The maximum IT value of each implant was recorded with the INTRAsurg 300 (Kavo Dental Ltd, Amersham, United Kingdom). The IT was increased from 20 Ncm in 5-Ncm increments until the operator was unable to rotate the implant due to friction before completion insertion of the implant. The insertion torque was aimed to be within 30 – 50 Ncm and adjusted by using a larger implant or rotating the implant in the opposite direction, if the value was out of the range.

Resonance frequency measurements

Evaluation of resonance frequency analysis (RFA) was performed immediately after implant placement using the Osstell device (Integration Diagnostics AB). The SmartPeg were mounted on the implants and manually screw-tightened. The RFA value was measured four times in each of the four directions (mesial, distal, buccal and lin-

gual) for each implant. RFA values are represented in the unit called the implant stability quotient (ISQ), which ranges from 1 to 100. A higher ISQ value indicates greater stability.

Statistical analysis

SPSS statistical software (SPSS, IBM) was used for comparative analysis of the data. The Pearson test was used to determine correlations between bone density, IT values, and ISQ values with respect to implant recipient regions, implant dimensions and patient sex and age (older versus younger). For comparative analysis, the Student t test for independent variables was used to analyze differences in bone density, IT values, and ISQ values based on age, sex, and treated arch. P values ≤ .05 were considered to be significant.

Ⅲ. RESULTS

Figure 1 presents the three-dimensional images of implants showing bone types and corresponding Hounsfield units, generated by OnDemand® software.

Table 1 shows the bone density, insertion torque values, and RFA values with respect to sex, age, type of implant and type of bone. The mean bone density, maximum insertion torque values and mean resonance frequency analysis (RFA) values of all 60 implants were 404 ± 165 HU, 36.1 ± 4.9 Ncm and 76.0 ± 6.1. It was found that the bone density in all patients ranged from 48 to 780 HU. For all implant sites, there was a statistically significant relationship between bone density values and insertion torque

measurements as well as between bone density and RFA values ($p<.05$) (Table 1 and Figure 2).

The mean bone density, insertion torque and RFA values were 311 ± 158 HU, 37.0 ± 3.4 Ncm, 74.5 ± 7.5 for 20 implants placed in females, while corresponding values were 451 ± 150 HU, 35.6 ± 5.5 Ncm, and 76.8 ± 5.2 for 40 implants placed in males. The differences between females and males were statistically significant in HU values ($p < .001$), but not in IT and RFA values ($p> .05$) (Table3).

The mean bone density, insertion torque and RFA values were 362 ± 134 HU, 36.0 ± 3.5 Ncm, 76.1 ± 5.6 for 26 implants placed in younger group, while corresponding values were 436 ± 181 HU, 36.2 ± 5.8 Ncm, and 76.0 ± 6.5 for 34 implants placed in older group. The older group showed higher mean bone density values, but the difference between younger and older group was not statistically significant ($p> .05$) (Table4).

The mean bone density, insertion torque and RFA values were 434 ± 1173 HU, 36.8 ± 6.1 Ncm, 76.3 ± 5.9 for 30 implants placed in SLActive group, while corresponding values were 374 ± 154 HU, 35.2 ± 3.2 Ncm, and 75.7 ± 6.4 for 30 implants placed in CMI group. There were no statistically significant differences in mean bone density, insertion torque, RFA values between two implant groups (Table 6).

According to Misch's classification, the bone of posterior maxillae in this study was classified as D3 (37) or D4 (23). The mean bone density, insertion torque and RFA values were 508 ± 111 HU, 37.8 ± 5.4 Ncm, 77.9 ± 5.1 for 37 implants placed in D3 group, while corresponding values were 237 ± 78 HU, 35.0 ± 3.7 Ncm, and 72.9 ± 6.4 for 23 implants placed in D4 group. For bone type 3 group, there was a statistically significant relationship between bone density values and insertion torque measurements ($p<.05$) whereas bone type 4 group. When compared to bone type 4 group (72.9 ± 6.4), significantly higher RFA values were found for bone type 3 group (77.9 ± 5.1, $p<.05$) (Table5).

Table 2 presents the RFA values, bone density, insertion torque values, and corresponding correlations with respect to implant dimension. For all implants, there was a statistically significant relationship between bone density values and diameter of implant ($p<.001$), but not in insertion torque values and RFA values.

Ⅳ. DISCUSSION

Bone quality has been one of the most important factors for long-term success of dental implants [23]. One of the most popular methods for bone quality assessment was proposed by Lekholm and Zarb. However this classification recently been questioned due to poor objectivity and reproducibility. In order to overcome the limitations of this classification, the evaluation of the bone density using CT is presented as objective and reliable method has been in utilized several studies.

Fuster-Torres et al reported that the mean bone density value in the posterior maxilla was 464 HU for 25 implant sites [24]. The study by Norton and Gamble stated that the mean bone density in the posterior maxillary region was 417 HU for 27 implant sites [8]. Turkilmaz et al reported that the mean bone density value in the posterior maxilla was 403 HU for 70 implant sites [25]. However Shapurian et al reported that the mean bone density value in the posterior maxilla was 333 HU for 54 implant sites [7]. In the present study, we obtained results similar to those reported by Turkilmaz et al. [25]. The differences between the present and other previous studies might result from the variations in patient-related factors (i.e., age, gender). Isoda et al reported that HU values evaluated by CT show high correlation with the primary stability values [15]. And Turkyilmaz et al also reported that statistically significant correlations are found be-

tween HU and IT values, HU and RFA values [26]. These results were also found in our study.

It is generally found that younger patients have lower bone density [26, 27]. In the present study, younger patients had lower bone density values; this fact may be a result of the small difference in age between the two groups, and the difference in values was not significant.

Turkilmaz's results [26, 27] show statistically significant difference in mean bone density was observed between men and women, and these results are in agreement with our study. However Shapurian et al reported that no statistically significant difference in mean bone density was observed between men and women [7]. Our results were consistent with those reported by Turkilmaz et al. So, further studies with a large sample of patients are needed to better understand the relationship between age, gender, and bone density.

Primary stability is a crucial factor especially when immediate/early loading protocol is considered. Roccuzzo et al suggested that, for immediate loading, single implant must be inserted with a torque greater than or equal to 30 N cm and multiple splinted implants must be inserted with a torque greater than or equal to 20 N cm [28]. In this study, the mean maximum IT values (36.1±4.9Ncm) and RFA values (76.0±6.1 ISQ) were recorded. In the present study, the difference in mean maximum IT and RFA values between men and women, and between the older and the younger groups, was statistically not significant. Therefore, it may be possible to overcome a risk of poor stability in the areas of such as using an implant with a larger diameter.

In this study, the primary stability values were not statistically different between two types of implants. These results were consistent with those reported by Rozè et al although different implant systems (Straumann and Ankylos) were used [22]. On the other hand, O'sullivan et al investigated the primary stability of five types of implant of vary-

ing geometry and surface topography. They concludes that all of the implants tested demonstrated good primary stability in type 2 and 3 bone while the Mark IV implants showed a high primary stability in Type 4 bone [29]. However, these results should be interpreted with caution. Rabel et al compared different implant systems of 263 patients and reported that the ISQ values obtained from different implant systems are not comparable and that RFA does not appear suitable for the evaluation of implant stability when used alone. The authors concluded that ISQ values should be calibrated for each implant system separately and can be used to ascertain different healing phases and the stability of dental implants [30].

Primary stability is influenced by various factors, such as the length and diameter of the implant, its design, the micro-morphology of the implant surface, the insertion technique and the congruity between the implant and the surrounding bone [31]. Further important factors are the quality and quantity of the bone [32]. However, there are various opinions about the impacts of the implant type or geometry as to how effectively they improve the primary stability in different bone types.

Winter et al demonstrated that the implant length did not have any significant effect on ISQ values in cases of a higher level of bone stiffness [33]. However, when the lower level of bone stiffness was used, an increase in implant length resulted in an increase in implant primary stability. Bischof et al concluded that length and diameter of the implants have no significant effects on the ISQ [34]. Ostman et al reported that it is possible to obtain a higher ISQ values by using of wide platform implants [35]. In contrast, lower ISQ values were reported as the length of the implants increased. Bilhan et al compared different implant diameters of 3.8 mm and 4.6 mm in cancellous bone and found no statistically significant differences in ISQ values [36]. Garcia et al postulated that the implant diameter did not have any significant effects on primary implant stability both in D1 and D2 bone types [37]. Barikani et al reported that implant length did

not have any significant influence on primary stability with implant site of high bone quality [38]. However, in cases of poor bone quality, a positive correlation was observed between the implant length and stability. So, they suggested that in area with poor bone quality and inadequate bone height bone augmentation should be performed rather than applying short implants. In this study, implant diameters showed a strong correlation between with HU, but not with IT or ISQ values. Our results also proved that it was possible to achieve sufficient primary stability of the implants with 10 mm in length for early loading by changing the diameter of the implant. This can be because a certain level of ISQ and IT can be obtained by using a larger diameter when bone quality is poor.

Regardless of implant systems used in the present study, a strong correlation between HU and IT values was observed. However, when comparing different bone types, only the type D3 group exhibited a correlation. A possible reason for this finding might be that the effect of HU on IT is offset by using the implant with a larger diameter in the type D4 group. For IT and ISQ, the mean values in the D3 group were greater than those in the D4 group, but only the difference in the ISQ values gained statistical significance. Based on this result, it can be considered that bone quality affects the ISQ values more than the IT values.

In short, our results demonstrated that the use of a larger implant was not effective enough to overcome poor bone quality and improve primary stability. Therefore, in order to obtain proper primary stability in such cases, clinicians should carefully plan the course of treatment and be cognizant of the future healing period, the loading protocols and the prosthetic components.

Ⅴ. CONCLUSION

Within the limitation of this study it can be concluded that the bone quality is more influenced by gender rather than age and the type of implant does not have a significant impact much on primary stability. And the results of this study suggest that the bone density evaluated by CT showed a significant correlation with the primary stability parameters. These values can provide the implant surgeon with an objective assessment of bone quality, which could result in modification of surgical technique, especially in situation where poor bone quality is suspected.

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Table 1. Mean Hounsfield units, maximum insertion torque, and implant stability quotient values and corresponding correlations with sex, age, and types of implants and bone

Group		No. of patient	No. of implant	Mean bone density (HU±SD)	Mean IT (±SD)	Mean ISQ (±SD)	HU-IT r	HU-IT P	HU-ISQ r	HU-ISQ P
Total		30	60	404±165	36.1±4.9	76.0±6.1	0.326	<.05	0.389	<.05
Sex	**Male**	20	40	451±150	35.6±5.5	76.8±5.2	0.415	<.05	0.281	>.05
	Female	10	20	311±158	37.0±3.4	74.5±7.5	0.474	<.05	0.457	<.05
Age	**≤60**	13	26	362±134	36.0±3.5	76.1±5.6	0.407	<.05	0.417	<.05
	>60	17	34	436±181	36.2±5.8	76.0±6.5	0.306	>.05	0.396	<.05
Type of implant	**SLActive**	15	30	434±173	36.8±6.1	76.3±5.9	0.462	<.05	0.179	>.05
	CMI	15	30	374±154	35.3±3.2	75.7±6.4	0.005	>.05	0.602	<.05
Type of bone	**D3**		37	508±111	36.8±5.4	77.9±5.1	0.354	<.05	0.054	>.05
	D4		23	237±78	35.0±3.7	72.9±6.4	0.178	>.05	0.254	>.05

P and r values were calculated by the Pearson test.
HU = Hounsfield unit; IT = insertion torque; ISQ = implant stability quotient

Table 2. Mean Hounsfield units, maximum insertion torque, and implant stability quotient values and corresponding correlations with implant dimensions

Implant dimensions (mm)	Type	No. of patient	No. of implant	mean bone density (HU±SD)	mean IT (±SD)	mean ISQ (±SD)	HU-IT r	HU-IT P	HU-ISQ r	HU-ISQ P
4.0 * 10	CMI	2	4	386±161	35.0±0	79.3±1.7	-	-	0.846	>.05
4.1 * 10	ITI	12	24	473±161	37.5±6	76.4±6.1	0.39	>.05	0.214	>.05
4.5 * 10	CMI	10	20	409±134	35.5±4	75.4±5.6	-0.156	>.05	0.625	<.05
4.8 * 10	ITI	3	6	277±136	34.2±4	76.1±5.4	0.673	>.05	0.046	>.05
5.0 * 10	CMI	3	6	255±176	35±3.2	74.0±10.3	0.408	>.05	0.722	>.05

P and r values were calculated by the Pearson test.
HU = Hounsfield unit; IT = insertion torque; ISQ = implant stability quotient

Table 3. Comparisons of average Hounsfield units, maximum insertion torque, and implant stability quotient values with patient sex

Parameter	Sex	N	Mean value±SD	t	P
HU	**Male**	40	451±150	3.34	<.05
	Female	20	311±158		
IT	**Male**	40	35.6±5.5	-1.03	>.05
	Female	20	37.0±3.4		
ISQ	**Male**	40	76.8±5.2	1.388	>.05
	Female	20	74.5±7.5		

P values were calculated by the Student t-test.
HU = Hounsfield unit; IT = insertion torque; ISQ = implant stability quotient

Table 4. Comparisons of average Hounsfield units, maximum insertion torque, and implant stability quotient values with patient age

Parameter	Age	N	Mean value±SD	t	P
HU	**≤60**	26	362±134	-1.76	>.05
	>60	34	436±181		
IT	**≤60**	26	36.0±3.5	-0.168	>.05
	>60	34	36.2±5.8		
ISQ	**≤60**	26	76.1±5.6	0.106	>.05
	>60	34	76.0±6.5		

P values were calculated by the Student t-test.
HU = Hounsfield unit; IT = insertion torque; ISQ = implant stability quotient

Table 5. Comparisons of average Hounsfield units, maximum insertion torque, and implant stability quotient values with type of bone

Parameter	Type of bone	N	Mean value±SD	t	P
IT	D3	37	37.8±5.4	1.386	>.05
	D4	23	35.0±3.7		
ISQ	D3	37	77.9±5.1	3.357	<.05
	D4	23	72.9±6.4		

P values were calculated by the Student t-test.
Bone type was based on Misch's classification.
HU = Hounsfield unit; IT = insertion torque; ISQ = implant stability quotient

Table 6. Comparisons of average Hounsfield units, maximum insertion torque, and implant stability quotient values with type of implant system

Prameter	Type of implant	N	Mean value±SD	t	P
HU	**SLActive**	30	434±173	1.411	>.05
	CMI	30	374±154		
IT	**SLActive**	30	36.8±6.1	1.195	>.05
	CMI	30	35.3±3.2		
ISQ	**SLActive**	30	76.3±5.9	0.43	>.05
	CMI	30	75.7±6.4		

P values were calculated by the Student t-test.
HU = Hounsfield unit; IT = insertion torque; ISQ = implant stability quotient

Figure 1. Three-dimensional images of implants showing bone types and corresponding Hounsfield units, generated by OnDemand® software (Cybermed, Seoul, Korea): (left) CMI implant and (right) SLActive implant

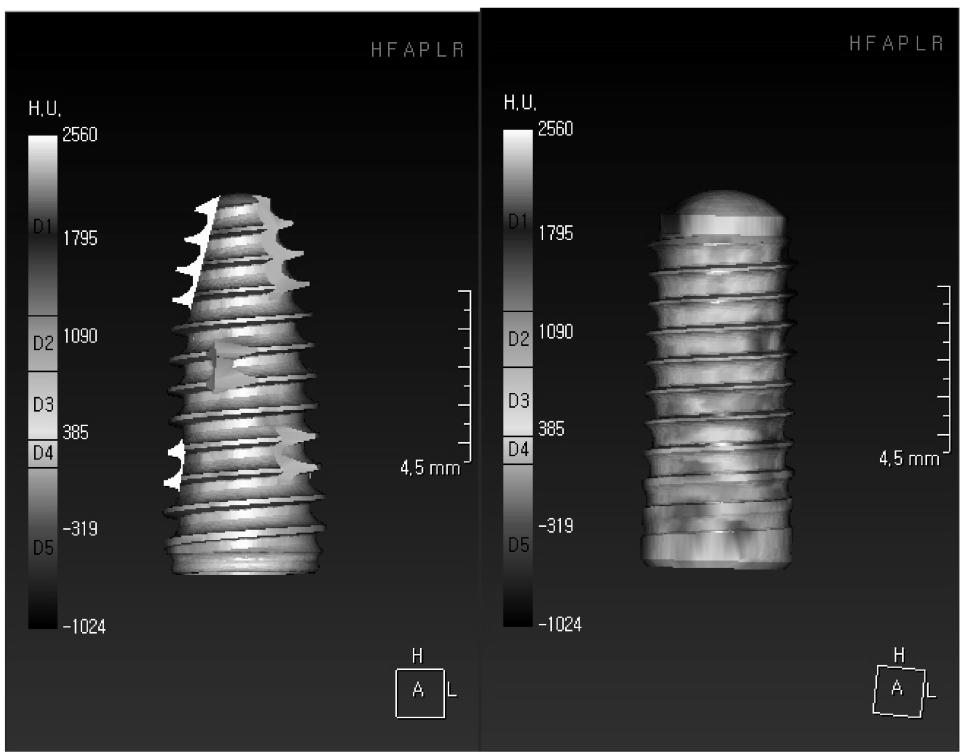
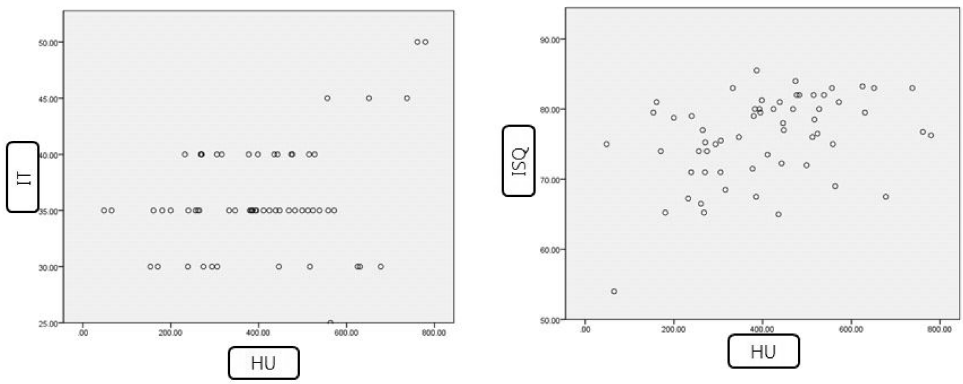


Figure 2. Scatter plots of Hounsfield units (HU) vs. insertion torque (IT) (left) and Hounsfield units vs. implant stability quotient (ISQ) (right)



- 국문초록 -

상악 구치부에서 골질과 임플란트 초기 안정성 사이의 상관 관계에 관한 연구

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1. 목 적

임플란트 치료 시 식립 부위의 골질과 초기 안정성 지표는 임플란트의 성공에 중요한 요소로 알려져 왔다. 본 연구의 목적은 상악 구치부의 임플란트 식립 부위의 골밀도를 컴퓨터 단층 촬영장치(CT)를 이용한 Hounsefield Unit(HU)로 평가하고 나이, 성별, 임플란트의 종류와 직경, 최대식립토크 측정치와 공명주파수분석 측정치와의 연관성을 알아보고자 하는 것이다.

2. 방 법

상악구치부에 총 60개의 임플란트를 식립한 30명의 환자를 평가하였다. 30개의 SLActive Bone level implant 와 30개의 CMI IS-II active 의 두 가지 종류 임플란트가 사용되었다. 각 임플란트 식립 부위의 골밀도는 CT를 통해 평가하고

이를 Misch의 골 분류법에 따라 나누었다. 최대식립토크 및 공명주파수분석을 시행하여 각각의 수치를 나이, 성별, 임플란트의 종류 및 직경, 골질 에 따른 연관성 및 차이를 Pearson test 및 Student t test 를 이용하여 분석하였다.

3. 결 과

총 60개의 임플란트에 대한 평균 골밀도, 최대식립토크, 평균 공명주파수분석 수치는 404 ± 165 HU, 36.1 ± 4.9 Ncm 그리고 76.0 ± 6.1였다. 모든 임플란트에 대해 골밀도 수치와 최대식립토크 수치 및 공명주파수분석 수치는 통계학적으로 유의미한 상관관계를 보였다($p<.05$). 골질을 3형과 4형으로 나누어 분석하면 3형 골질 그룹에서는 골밀도 수치와 최대식립토크 수치 사이에서 상관관계가 있었으나($p<.05$), 4형 골질 그룹에서는 상관관계를 보이지 않았다($p>.05$).

4형 골질 그룹과 비교 시 3형 골질 그룹에서 통계학적으로 유의미하게 공명 주파수 분석 수치가 높았다(4형 그룹: 72.9 ± 6.4, 3형 그룹: 77.9 ± 5.1, $p<.05$). 여성 그룹에서 보다 남성 그룹에서 골밀도 수치가 유의미하게 높았다(여성 그룹: 311 ± 158, 남성그룹: 451 ± 150, $p<.05$). 또한 두 임플란트 그룹 사이에 평균 골밀도와 최대 식립 토크 및 공명 주파수 측정치 사이의 통계적으로 유의미한 차이는 없었다($p>.05$).

컴퓨터 단층 촬영을 통한 골밀도는 임플란트의 초기 안정성 지표들과 유의미한 상관관계를 보였다. 이러한 수치들은 임플란트 식립 시 술자에게 골질의 객관적인 정보를 제공하여 골질이 좋지 않은 상황에서 유용하게 쓰일 수 있음을 확인하였다.

주요어 : 골밀도, Hounsfield Unit, 상악구치부, 최대 식립 토크, 공명 주파수 분석

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